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AVERAGE DEPTH OF SNOW IN UNDULATING LAND IN FINLAND

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Abstract

In this investigation a comparison between average snow depth on slopes not far from each other in mid-winter 1952–63 in Finland has been carried out. Whirlwinds, drifting of snow, blizzards and interception may account for variation in the average results of comparison in different parts of the country.

Introduction

When measuring depth of snow in undulating land in mid-winter it is observed that even in small areas the average depth of snow may vary on different slopes inspite of similarity of vegetation. As chief factors accounting for this the whirlwinds during snow fall, drifting of snow, blizzards and interception of different degree may be considered. In general up to mid-winter insolation has not yet affected the snow cover in any significant degree.

The dispersion of snow depth on even the same slope may vary in a great degree. Should an accuracy of 1 cm be necessary in determining the average depth of snow cover it would require measurements in a large number of points.

Snow course is the most frequently used method of measuring snow depth in Finland. Snow course route covers different types of land and in general also undulating land. But inspite of the ample amount of snow depth measurements at any one of snow courses a far too small number of depth measurements falls on slopes for providing an accuracy of 1 cm in calculating the average depth of snow cover on slopes based on one snow course only, as the observation points are distributed over all different lands and different slopes.

Snow course measurements in Finland have been operated during several decades (KORHONEN [4], KAITERA [2], SIRÉN [8], SEPPÄNEN [7], MUSTONEN [6]). During each snow course measurement notes are made on the direction of inclination and the steepness of slope at the observation point. However, evidently the small amount of observation points falling on slopes may account for the fact that data on accumulation of snow on different slopes based on snow course measurements in Finland have not been published. HEIKINHEIMO [1] has carried out a special research with reference to the influence of relative altitude on the amount of snow accumulating on slopes of arctic hills.

However, comparison between snow accumulation on different slopes may have some significance from the hydrological point of view. Hence in this investigation I have endeavoured to carry out a comparison between average snow depth on slopes, hilltops, in dale bottoms and on level ground situated not far from each other and present the results of comparison as mean values of the observation data of different snow stations.

For obtaining an adequate number of observations for different slopes, the slopes in this investigation have been divided into 8 groups according to direction of inclination: N., NW., W., etc. The investigation is based on snow course measurements of January 16, February 16, and March 16 during 1952—63 made at snow stations of the Hydrological Office. Measurements include some 200,000 points of observation altogether.

Considering the type of land the study is limited to open field or meadow, pine-dominated forest, spruce-dominated forest and birch-dominated forest.

The density of the forest, points of observation as regards to slopes or the steepness of slope have not been taken into account. The results present the weighted means of snow depth with reference to different types of land and the direction of inclination of slopes.

Observational data

During 1952—63 the Hydrological Office had in operation some 100 snow course stations where the measurements were made on the 16th of every winter month. In general the snow course forms a square with

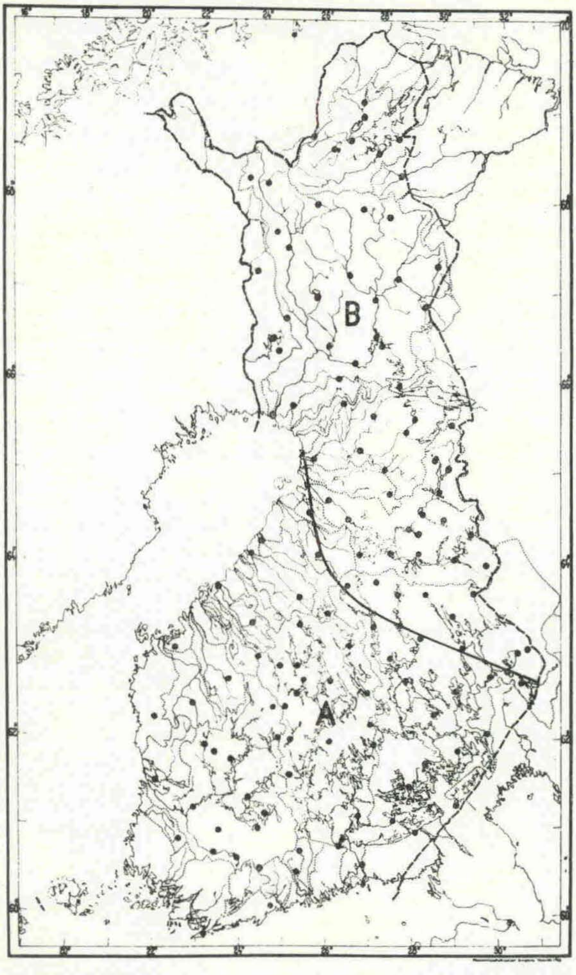

Fig. 1. Snow course stations of the Hydrological Office in 1952—63. Areas A and B are separated by the freezing-point isotherm of the daily mean maximum air temperature of November.

sides 1 km long. The depth of snow is measured at every 50 metres and one snow course includes snow depth measurements in 80 points.

Fig. 1 shows the snow course stations of the Hydrological Office in 1952—63 in Finland. In this work I have divided the country into two areas, A and B, on the basis of the freezing-point isotherm of the average daily maximum air temperature of November, drawn according to Kolkki [3]. The subdivision is accounted for by the fact that mild weather occurs more frequently in area A than in area B.

However, only a rough evaluation can be presented here, as it is difficult to determine accurately the amount of precipitation falling on the areas with the size of A and B during different wind directions.

At the precipitation stations of the Hydrological Office the precipitation is measured at 08.00 h. Thus the measurement of air temperature and wind carried out at 20.00 h falls mid-way of two consecutive precipitation measurements, *i.e.* in the middle of the 24 h precipitation period.

The average precipitation for areas A and B is calculated as the mean of measured amounts of two precipitation stations. In area A the precipitation has been determined by the observation data of precipitation stations Vammala (61°.3 N, 22°.9 E) and Iisvesi (62°.7 N, 27°.0 E) and in area B by Kittilä (67°.6 N, 24°.8 E) and Kuusamo (65°.6 N, 29°.5 E) respectively.

In each area air temperature and wind observations (at 20.00 h) were taken from an airport weather station of the Meteorological Office, the observations of which can be considered to correspond with the actual average values of air temperature and wind of the respective areas. In area A the air temperature and wind observations of Luonetjärvi airport (62°.4 N, 25°.7 E) were used and in area B the respective observations of Rovaniemi airport (66°.6 N, 25°.8 E).

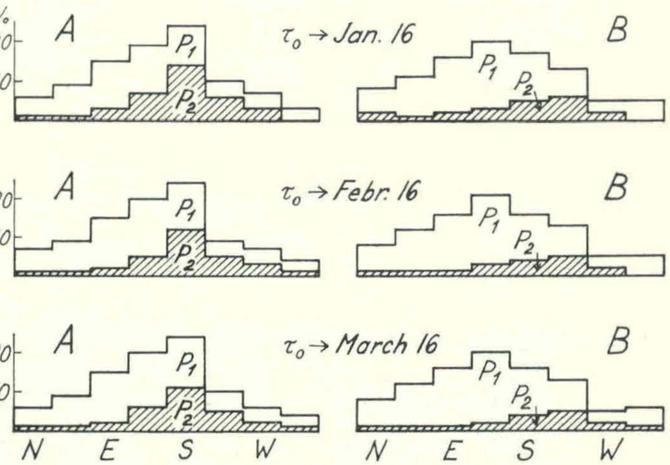

Fig. 2. Average distribution of dry (P_1) and wet (P_2) precipitation according to different wind direction from the beginning of winter (τ_0) to date of observation in areas A and B in 1952—63. Amount of precipitation is expressed as percentage of the corresponding total precipitation of the areas respectively.

In this investigation precipitation is considered dry with the air temperature below freezing point during precipitation and wet with the air temperature at or above freezing point respectively. Fall of wet snow in Finland has been studied by LAVILA [5].

Results of computations are seen in Fig. 2. The beginning of winter is marked by τ_0 indicating the date of the beginning of permanent snow cover. It is observed that from the beginning of winter to each date of observation in 1952—63 wet precipitation (P_2) amounted to 1/3 of all precipitation in area A and to 1/6 in area B respectively. Thus wet precipitation in area A was about twice the amount that reached area B. Further it is observed that wet snow reached area A mostly with prevailing southerly winds and in area B with southwesterly and southerly winds respectively. Dry snow (P_1) reached the ground in both areas mostly at southeasterly winds.

Average snow depth on different slopes

The snow course measurements, on which this investigation is based, were carried out in ordinary typical Finnish landscape with its topography relatively flat, there slopes usually are gently slooping, sometimes moderately steep and seldom precipitous. Relative altitudes along snow course routes are so small that they have no significance considering the results of measurement.

The depth of snow on slopes at every snow station is compared with the average snow depth of such an open field or meadow which had been on level ground according to the observator.

The investigation has reference to the snow depth on slopes distributed not far from each other on an area of about 1 km² in areas with the size of A and B, where a great number of snow course stations exists.

Average snow depth on slopes with certain direction of inclination is computed from the equation 1.

$$h = \frac{100\left(\sum_{i=1}^{m} h_i^{(1)} + \sum_{i=1}^{n} h_i^{(2)} + \dots\right)}{mh_0^{(1)} + nh_0^{(2)} + \dots} \% \tag{1}$$

The snow depth is expressed as percentage of average snow depth on open field or meadow on level ground close to.

In the equation $h_i^{(1)}$ denotes snow depth of one snow station where the average depth of snow on open field or meadow on level ground was $h_0^{(1)}$, on another station the values are $h_i^{(2)}$ and $h_0^{(2)}$ etc. respectively.

Results of computation are seen in Fig. 3. The average snow depth on open field or meadow on level ground is marked 100%. The continuous line presents the average depth of snow on different slopes in area A and the dashed line in area B respectively.

Average snow depths on open field or meadow on level ground were:

	January 16	February 16	March 16
Area A	36 cm	47 cm	53 cm
Area B	48 »	60 »	67 »

With the aid of these numbers, the values expressed as percentage in Fig. 3, the average depth of snow may be calculated and expressed in cm. However, if the simultaneous average snow depths expressed as percentage in Fig. 3 are equal in both areas A and B, as for instance on southeast slopes of open field or meadow (98%) on March 16, they have

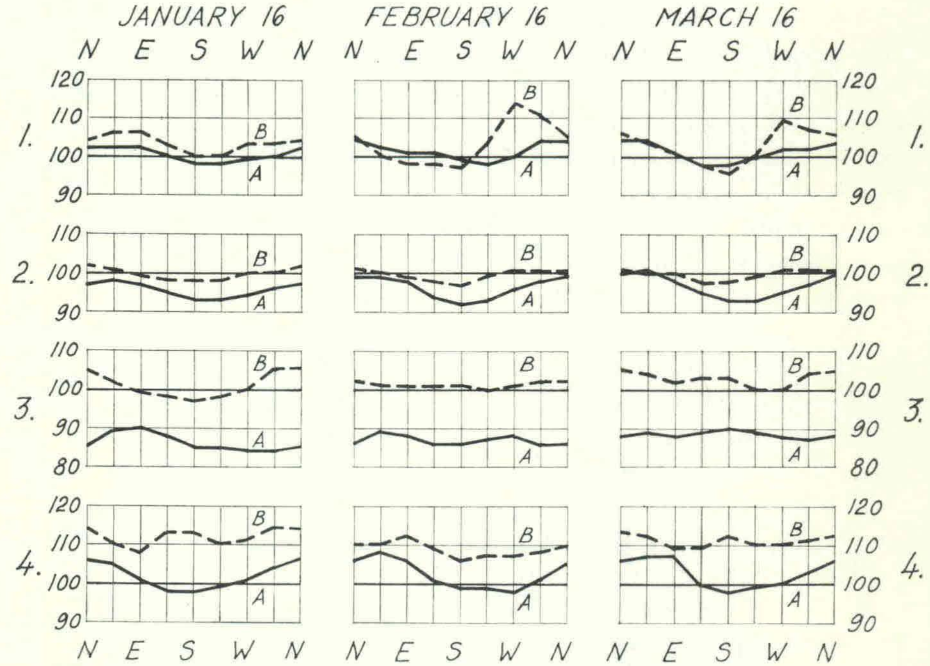

Fig. 3. Average percentual snow depths on slopes on 1 km²-area on the average in 1952–63. 1 = open field or meadow, 2 = pine-dominated forest, 3 = spruce-dominated forest, and 4 = birch-dominated forest. A = in area A and B = in area B.

not the same value expressed in cm. The corresponding average depth of snow in area A is 52 cm and 66 cm in area B respectively.

In the following, when the snow depth is discussed the average depth of snow is indicated.

In Fig. 3 the great snow depth (114%) in area B on west-side slopes of open field or meadow on February 16 calls for special attention. On the same slope the snow depth had been 103% one month earlier.

During the time interval between January 16 and February 15 in 1952—63 precipitation in area B consisted almost only of dry snow and the major snow fall was obtained with prevailing easterly winds. Increase of snow depth (Δh) at the time interval referred to on different slopes of open field or meadow expressed as percentage of increase of snow depth on level ground of open field or meadow was as follows:

	Slopes								Level ground
	N	NE	E	SE	S	SW	W	NW	
h	110	80	65	82	86	115	154	139	100 (12 cm)

Increase of snow depth was particularly great on west slopes (154%) and least on east slopes (65%). Hence the depth of snow on west slopes of open field or meadow in area B was still considerably great (109%) on March 16.

Further it is seen from Fig. 3 that in pine-dominated forests in both areas A and B the snow depth was least on southerly slopes. One reason to this might lay in the fact that the greatest amount of precipitation was obtained with prevailing southerly winds, during which the whirlwinds may account for a greater accumulation of snow on northerly slopes. Another reason may have been in the interception of greater degree of wet precipitation than that of dry. The wet precipitation was obtained mostly by southerly winds when the precipitation falling obliquely reaches the tree branches on southerly slopes in a greater amount than on northerly slopes where it falls down nearby perpendicularly.

In pine-dominated forest in area A the snow depth was less than 100% on almost all slopes, but close to 100% in area B.

In spruce-dominated forest the snow depth was 90% or less on all slopes in area A, whereas in area B it was somewhat over 100%. Interception by spruce branches had been heavier in area A than in area B.

In birch-dominated forest the snow depth was somewhat below 100% on south slopes, but 105 to 108% on northwest slopes in area A. In area B the snow depth was in general close to 110% on all slopes.

Average snow depth in undulating land

The snow course route crosses different slopes, hills, ridgetops, goes through dale bottoms and proceeds on such a land where the ground is level according to the observator. All the mentioned land types are found as well on open field or meadow as in forest.

Table 1 presents snow depth in undulating land during the mid-winter in 1952–63. The time interval between January 16 and March 16 is indicated as mid-winter.

Table 1. Snow depths in undulating land in mid-winter (considered as the time interval between January 16 and March 16) on 1 km² area expressed as percentage of the average snow depth on open field or meadow on level ground in 1952–63.

Type of ground	Lands	h (%)	
		Area A	Area B
Level	Open field or meadow	100 (45 cm)	100 (58 cm)
	Pine-dominated forest	97	101
	Spruce-dominated forest	89	102
	Birch-dominated forest	103	108
Hilltop	Open field or meadow	91	93
	Pine-dominated forest	94	94
	Spruce-dominated forest	87	96
	Birch-dominated forest	96	104
Dale bottom	Open field or meadow	109	120
	Pine-dominated forest	106	106
	Spruce-dominated forest	100	111
	Birch-dominated forest	109	108
Slopes	Open field or meadow	101	103
	Pine-dominated forest	96	99
	Spruce-dominated forest	87	101
	Birch-dominated forest	102	111

From Table 1 the following is seen:

On level ground minimum snow depth (89%) is found in spruce-dominated forest in area A and the maximum (108%) in birch-dominated forest in area B.

On hilltops minimum snow depth (87%) appears in spruce-dominated forest in area A and the maximum (104%) in birch-dominated forest in area B.

In dale bottoms the minimum snow depth (100%) is found in spruce-dominated forest in area A and the maximum (120%) in open field or meadow in area B.

On slopes minimum snow depth (87%) occurs in spruce-dominated forest in area A and the maximum (111%) in birch-dominated forest in area B.

It is observed that in area A the minimum snow depth in general is found in spruce-dominated forest compared to snow depth in whichever other type of ground.

It is further seen from Table 1 that in general the snow depths expressed in percentage are smaller in area A than in area B. This may be caused by many factors. For instance, one factor may be the fact that wind may have driven less snow from open level ground in area A than in area B while in area A mild weather occurs more frequently, after which the snow flakes get stuck together by freezing. Another reason may be the interception of snow by trees in greater degree in area A since more wet precipitation reached area A than area B from the beginning of winter until the date of observation.

The organization of observations which this investigation is based upon, was not initiated for studying problems referred to. The results presented in this investigation do not deal with any detailed snow depths in different points of an undulating land. A particularly organized special study is required for this purpose. The attention should be focused to greater accuracy considering meteorological factors for providing insight into the cause of variation of snow depths in observation points not far from each other in undulating land.

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